Examination of health effects and long-term impacts of deployments of multiple tag types on blue, humpback, and gray whales in the eastern North Pacific

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Award Number: N000141010902
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LONG-TERM GOALS

The goal of this project is to provide new insights into the long term consequences of different types of tags on several additional species of large whales including blue, humpback, and gray whales by conducting long term follow up of previously tagged individuals in the eastern North Pacific. We examine the long term impacts on health, reproduction, and mortality unitizing the past deployments of implant and suction cup tags on blue, humpback, and gray whales in the eastern North Pacific and our extensive monitoring of these populations. Despite extensive use of implant tags for more than 30 years (Mate et al. 2007), only limited studies have been conducted of the health effects and long-term consequences of tag deployments on whales. This field is rapidly expanding including increased use of deep penetration tags on many populations including critically endangered populations such as the North Pacific right whale and the western gray whale. Studies of North Atlantic rights whales revealed a wide variety of conditions of the tag site after deployments of penetration tags varying from very minor divots to more extensive swellings.

OBJECTIVES

The overall objectives for this multi-year project are as follows:

1. Examine the long-term survival of tagged animals in relation to animals that were not tagged.
2. Test for differences in the visual health status of tagged versus untagged animals.
3. Examine the condition of the tag site and evaluate healing in tagged animals.

APPROACH

Long term impacts of tagging are being examined by conducting detailed follow-up of blue, humpback, and gray whales that have had tags deployed on them to examine site healing, health, and any long-term consequences of tag deployment on reproduction, health, or survival. Our focus on three species of baleen whales in the Eastern North Pacific represents an ideal test case to study this for two primary reasons:

1. Some of the longest histories of tag deployments have been conducted in this area on these species. This includes over 400 deployments of a wide variety of tags ranging from suction-cup, external tags anchored into blubber, and full implant tags on blue whales (Mate et al. 1999, 2007, Bailey et al. 2009, Irvine et al. 2014, Lagerquist et al. 2000, McKenna et al. 2015, Goldbogen et al. 2011, 2012, 2013a, 2013b, 2014, 2015, Calambokidis et al. 2008). This sample includes the largest number of implant tag deployments of any whale population (OSU implant tag deployments on approximately 183 eastern North Pacific blue whales, for example).
2. Extensive sighting histories of blue, humpback, and seasonal-resident gray whales are available off the US West Coast from photo-identification studies; these studies have been virtually uninterrupted since 1986 with continued monitoring planned (Calambokidis et al 2002, 2010, 2014, Calambokidis and Barlow 2004, 2013). In all three species, the majority of the population has been photo-identified and resighting rates are very high. Seasonal resident gray whales in this region have annual resighting rates of 70% or more and catalogs of identified blue and humpback number over 2,000 individuals each.

We used both photographs and genetics to conduct the first systematic reconciliation of the animals tagged with the long-term photo-ID datasets. Photographs and video taken from deployments were used to catalog both the photo-ID identities and the markings immediately around the tag site of whales to add to those where a match between tagged animal and photo-ID has already been made and those gathered of during the study. Additional determinations of identity is being made based on genetic matches between samples taken from about 100 implant-tagged whales and those collected from animals in these populations.

WORK COMPLETED

The following major areas of work were conducted in 2015 (the project wraps up the end of 2015):

- Processed and matched identification photographs of blue and gray whales taken in 2014 to evaluate where previously tagged animals (or those selected as controls for tagged animals) had been resighted.
- Where new encounters with previously tagged animals were determined by photo-identification, we selected the best tag site photographs and added these to our tag site healing chronology.
- Continued work with collaborators at OSU genetics lab and Dr. Scott Baker to conduct additional genetic identification comparison of samples of our control animals to help

verify they are not any of the tagged animals for which adequate photo-identifications were not available.

- Continued our collaboration with OSU tagging team (Dr. Bruce Mate) to verify we have as complete and accurate records on their tag deployments and follow up photographs.
- Compile sighitng histories and follow up photographs of additional gray whales tagged by OSU in 2012 and 2013.
- Scored the updated tag site condition photographs from 2014 and with these tag site photographs have now been scored for 34 gray and 63 blue whale tagging events (995 total images) which reflect the full sample of whales tagged by OSU where we were able to positively assign a photo-ID and there were follow up sightings made post-tagging.
- Updated photographs including those from 2014 were scored by our team of expert veterinary pathologists.
- Conducted data analysis for survival rates working with Alex Zerbini to test for differences in survival rates.
- Conducted analysis of tag site injury working with Dr. Stephanie Norman and our veterinary pathology team of post tag condition of blue and gray whales.
- Prepared final report for project as well as two presentations of findings for the Biennial Conference on the Biology of Marine Mammals in San Francisco in December 2015.

RESULTS

Follow up and resighting rates

Summarized below are the results of different components of the research completed to date. The above additional efforts have increased the number of OSU implant tagged whales that now have a clear photo-identification suitable for tracking to 82 blue whales and 36 gray whales. These reflect updated results obtained during 2015 including the identification of additional animals from more detailed examination of photos taken during tagging as well as using more photos obtained through the 2014 field season which helped identify animals. We have also increased the years of resighting data available to include 2014 field effort and also to further score follow up wound healing. Results of genetic analyses conducted of whales satellite tagged by OSU have been completed and were summarized in the previous annual report. The updated summary of the whales that have been tagged that this study has sought to determine photo identifications of blue, humpback, and gray whales to allow follow up tracking of survival, tag site condition, and health effects are summarized below (Table 1).

Table 1. Summary of photo-ID of different species of whales tagged by OSU with implant or external satellite tags through 2014 field effort.

Species	Attach Type	Total Tags Deployed	Deployments whale photo-IDed	Unique identified whales Tagged
Blue whale	Satellite tag total	185	85	83
	External	56	19	19
	Internal	129	63	63
Gray whale PCFG -2009	Implant	18	18	18
Gray Whale PCFG-2012-13	Implant	17	17	17
Humpback	Implant	33	4	4

Our best sample for examining follow up comes from 18 PCFG gray whales OSU satellite tagged in the Pacific Northwest in fall 2009, all 18 were photo-identified either with photographs taken at the time or later and all were known animals present in Cascadia's catalog of eastern North Pacific gray whales. (Table 2). Cascadia maintains a catalog of eastern North Pacific gray whales that consists of about 1,000 individuals identified off California, Oregon, Washington, and British Columbia by Cascadia and other collaborators under a project primarily sponsored by the National Marine Mammal Laboratory (Calambokidis et al. 2002, 2010). The core of this catalog is the estimated 200-250 gray whales that regularly use the Pacific Northwest for feeding each spring, summer, and fall termed the Pacific Coast Feeding Group (PCFG). In addition to photo-ID, recent genetics studies have revealed significant differences in mtDNA between these animals and other eastern North Pacific gray whales suggesting these should be treated as an independent demographic unit (Frasier et al. 2011, Lang et al. 2014).

Resightings of the 2009 tagged PCFG whales through 2014 (Table 2) appears to be different compared to a control group of individuals (identified in the same area and time in 2009 but not tagged, Table 3, Figure 1). Overall, 17 of the 18 PCFG gray whales tagged in 2009 have been resighted in a subsequent year (2010-14). Highlighted in the table are three whales that either have not been seen Jan 2010 at the latest or in one case known to have died at the end of 2011 (CRC 411, a tagged whale known to have died in late 2011, though cause of death was not known and no examination conducted). While 3 of 18 (17%) tagged whales have not been resighted or were known to have died, the same was true for only 2 of 39 (5%) animals identified as controls (Table 3) which were selected due to their having been identified in the same region and time period as the tagged animals (but not tagged) and like the tagged animals were known individuals from the PCFG. A comparison of the rate of sightings of these controls showed they were similar to the tagged whales prior to the tagging year but diverge after tagging (Figure 1).

Table 2. Identification histories of PCFG gray whales that were tagged by OSU in fall 2009 with resightings through 2014. Numbers underneath years indicate the number of times the whale was sighted that year. Highlighted area indicates period whales not sighted in four or more consecutive years subsequent to tagging and in one case whale known to have died in 2011.

ID	TAG Number	Sex	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
32	PTT 5205938	F	2	16			18	3	6			2		**4**				2	
89	PTT 5223029	M	20	21	30	13	4	23	10	19	16	8	16	**19**	20	24	32	11	10
164	PTT 5210836	M			3	1	1			1	1		1	**9**	14	9	4	2	3
196	PTT 5210838	F			2		1	9		6	14	6	8	**21**	24	14	**32**	13	6
205	PTT 5210842	F		6	1	3	3	5					7	**19**	5	6			1
206	PTT 5205923	M	3	2	1	3	4	3				2		**10**	1	3	16	20	
215	PTT 5205670	M	1				5	4	1			3		**15**	2				
291	PTT 5223032	M	2	2	1	3	6	10	4	1	5		1	**10**	3	16	18	2	
302	PTT 5205801	F	4	8	1		4	14	10	1	15	6	15	**8**	16	14	14	27	25
411	PTT 5223038	F		1	4	8	4					2	3	**12**	7	11*			
525	PTT 5200847	F			1	2	1		1	2	1	4	23	**16**	4		1	7	2
537	PTT 5200831	M			2			1				1	1	**14**	12	5	7	5	1
615	PTT 5223033	M				1	1						2	**3**	5	4	4	1	
643	PTT 5204174	M				1	2	1		2			3	**13**	1	9	6	9	2
659	PTT 5200827	F					2		5		1		1	**19**	7	5	9		2
797	PTT 5223035	M						1	2	7	18	12	13	**7**					
854	PTT 5201385	M								1			3	**11**	8	9	5	17	9
981	PTT 5223041	M					1	2				1		**11**	7	8	22	13	2

Table 3. Sighting histories of 39 whales selected as controls for the 2009 tagged whales (seen in the same region and time period as the tagged whales and previously identified). Similar to Table 2, highlighted record is for a whale not seen in four or more consecutive years post 2009.

ID	Sex	1984	1986	1988	1990	1991	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
42	M	3		0	1		5	2	2	2		24	26	9	13	24	7	5	2	15	2	19	**10**					
87	M						2			2		24	12	36	18	10	8	5	3	10	1	13	**7**	7	18	17	2	3
107	M							2	1		2	7	1	34	10	1	15	11	9	10	3	13	**9**	25	29	24	17	20
123										1	3	8	6	9	8	22	10	8	7	21	1	2	**17**	7	30	26	26	5
127	F		1								4	1	3	26	19	1	14		9		4		**1**	20	13	4	10	4
166									2	2	5	9	9	22	22	9	15	13	6	11		6	**9**	2	1			5
204	F									1	1	1	2	45	3	5	14		10	3	4	3	**8**	11	16	14	29	7
277	F											4		1									**5**		9	10	9	
278	M											1			2	2	2		1				**2**	6	9	11	3	1
280	F											3				3	1			3	2		**10**	1	19	2	3	1
289	F					1						1		1	4	1					1		**6**	4	13			
297												2	2		4	1	1		1	2		1	**4**	1	1	8	1	1
364	F												1	2		3			1		6		**8**	11	11	14	7	4
365	M												1	1	3	4	3					1	**2**	5	17	12	6	7
464	M												1	2		6						1	**1**	3	7	7	7	
510	M													2	1	11	6	1		2	1	7	**3**	22	14	16	11	14
551	M													1		2							**3**	5	4	2	60	8
554	F										3			3	2	2	2	6		1	1	10	**11**	15	22		1	5
555	M													6		4	3			1		1	**9**	15	28	4	6	
565	F													1		2					8		**9**	7	12	17	26	14
583	F														5	1	6		6	2	12	13	**27**	4	18	3	3	1
657	F															2	1		1	1	3	2	**7**	4	3	14	6	1
669	F															3	2	1			1	1	**4**	9	3	2	1	4
696	M															3	16	11	14	15		21	**19**	24	41	28	20	
698	F															4	8	1	12	9	1	11	**3**	2	65	14	32	34
703	M															2		1			1		**5**		6		1	
759												3				16	9	17		2	2	26	**3**	1		1	1	
780	M																					4	**11**	11	23	7	7	5
791	M																7	3	3				**2**	4	20	18	17	3
840																			3			1	**10**	1	11	8	11	5
231	F											30	31			6	1	2	3	3	1	3	**4**	3	1	14	12	6
285	F					1									2	1							**2**	3	5	5	3	3
293												1			2	4	3	1			2		**1**		2	6	2	2
295	M					1						7			1	1	2	2	6	1	2	6	**3**	8	13	11	5	6
300												22	5	40			3			11	4	10	**7**	3				
319												2		3	13	2	1	1		3		20	**4**	2	4	8	8	
330	F										5	2				15		1					**2**			4		
611	F														4						1		**4**	3	9	5	10	1
639															1	2					1		**4**		5			

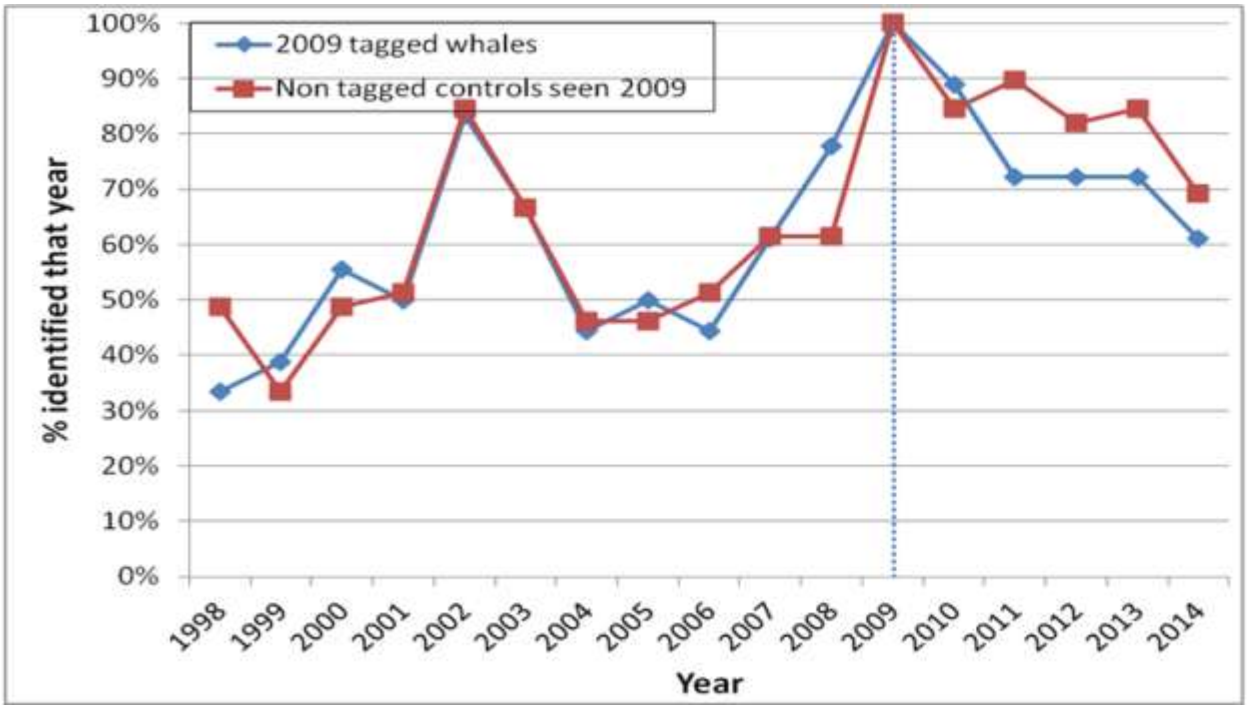

Figure 1. Proportion of tagged and control whales for 2009 tag deployments resighted for all years from 1998 to 2014 (see text).

A similar but more limited analysis (due the shorter time period post tagging) was conducted for the 11 PCFG gray whales tagged in 2012 compared to 25 non-tagged control whales (Figure 2). Agreement between tagged and control samples prior to the 2012 tagging was more variable than for the 2009 tagged sample, however, as was the case with 2009, there was a lower resighting rate of tagged animals more than 1 year post tagging.

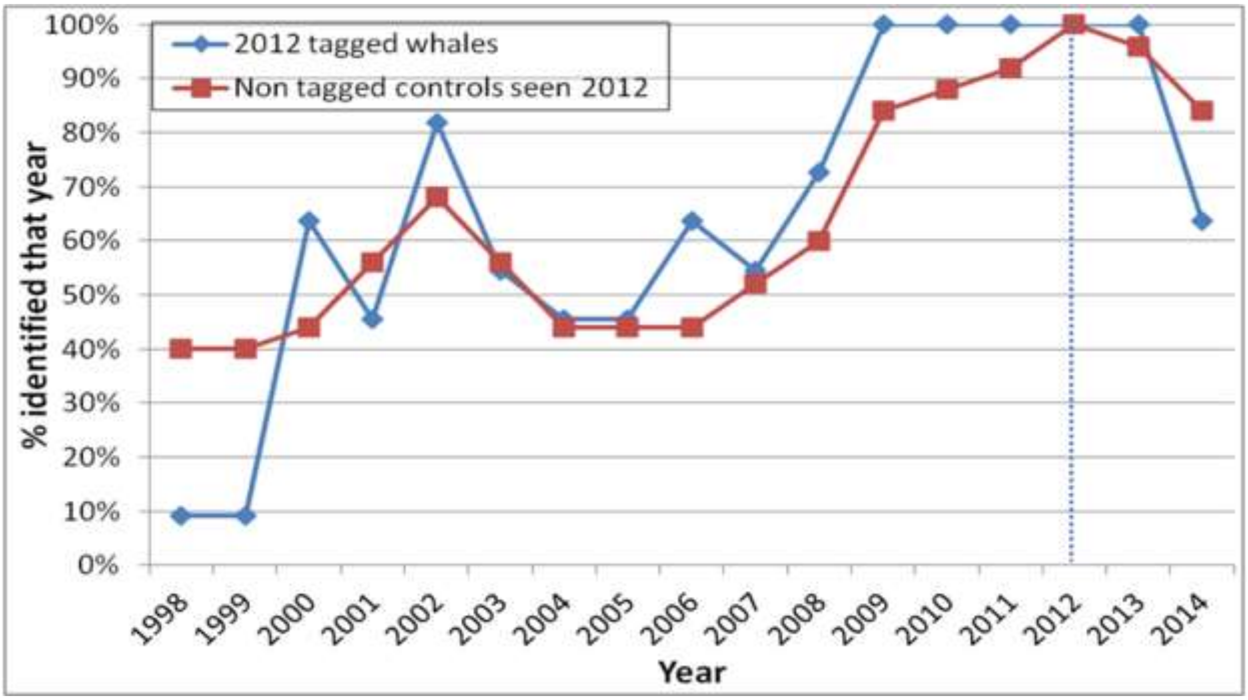

Figure 2. Proportion of tagged and control whales for 2012 tag deploymnets resighted for all years from 1998 to 2014.

Blue whales do not have as frequent a resighting history as the PCFG gray whales but this is somewhat offset by larger number of identification for tagged blue whales (Table 1). We have been able to improve the number of implant tagged blue whales with known identifications to 85 of the 185 tag deployments. Figure 3 shows the annual resighting rates of blue whales for both tagged and control animals for a 13-year period from 7 years pre-tagging to 5 years post-tagging. Consistent photo-ID data was available for 1986 to 2013 and tags were deployed from 1993 to 2008, so all tagged and control animals had the potential to be resighted within the 13 year span. Tagged whales were almost twice as likely to be encountered both in the years before and after tagging but despite this bias, there was no indication of a decrease in resighting rate for tagged animals in the years post tagging compared to control animals.

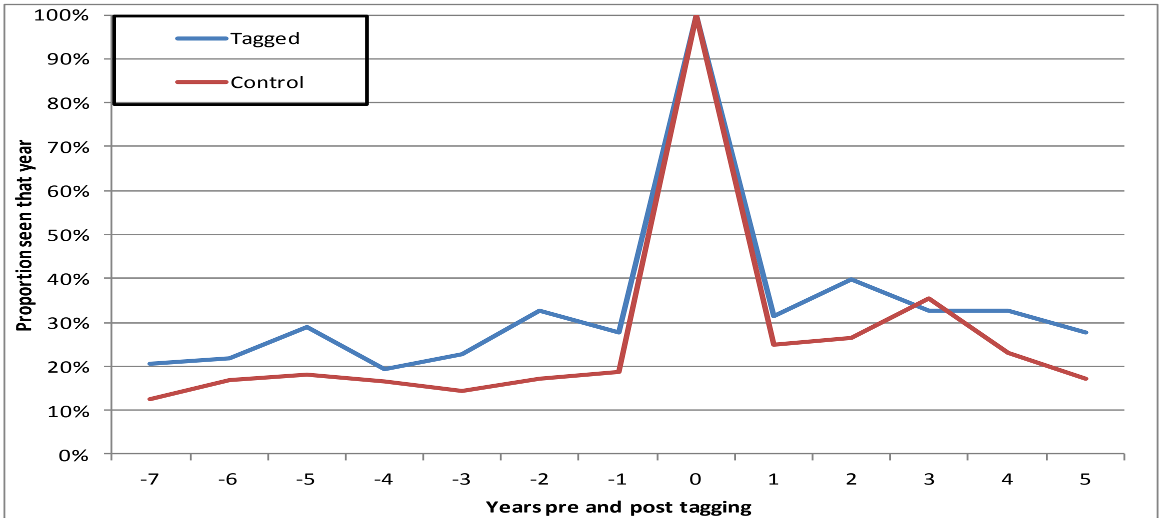

Figure 3. Resighting rate of blue whales for animals tagged by OSU and control animals seen in the same area and not tagged for the period from seven years prior to 5 years post tagging.

Survival rates for tagged and control PCFG gray whales and blue whales were examined for the years post tagging using Cormack-Jolly-Seber (CJS) capture recapture models. PCFG gray whales tagged in 2009 provided the ideal sample due to their high resighitng rates, five years of post-tag data, and high proportion of known sex animals (all 18 tagged whales and 30 of the 39 control animals). A total of 110 possible models were evaluated and the 9 most supported (Delta AICc <=2) models included those with and without tag effects. While models with tag effect showed a lower survival of tagged versus untagged whales it is not possible to unequivocally conclude there is an effect of tagging in survival probability. All the top models included a sex-related difference in capture probability likely as a result in differences in migration and behavior of females related to calving.

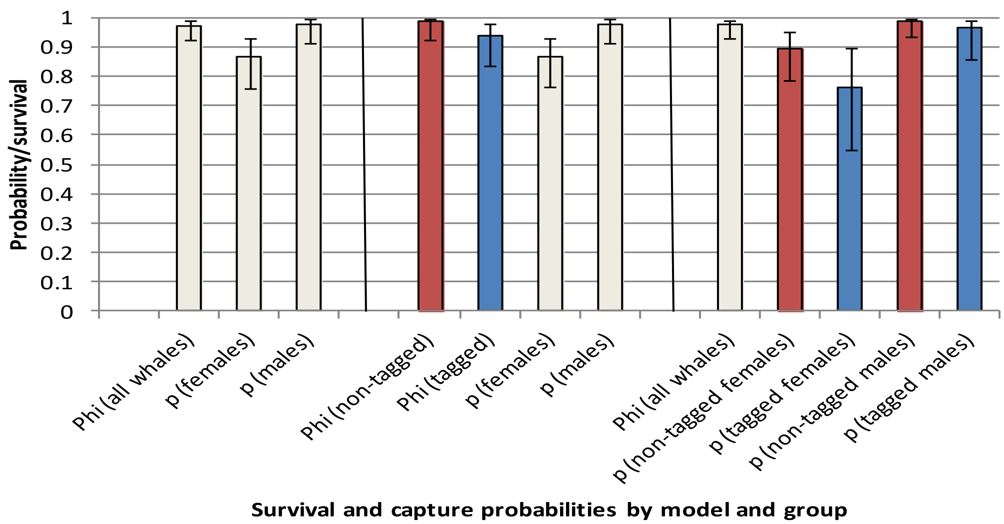

Figure 4. Comparison of survival (Phi) and capture probability (p) for PCFG gray whales tagged or controls from 2009 tag deployments comparing top three Cormack Jolly-Seber models based on data subsequent to 2009. Gray bars reflect tagged and controls and colored

bars reflect values for tagged (blue) or non-tagged controls (red) for models that distinguished based on tag status.

Tag site condition evaluation

Results of evaluation of the condition of the tag site has been conducted for tagged blue and gray whales using two approaches: 1) objective scoring conducted independently by two researchers (Stephanie Norman and Kiirsten Flynn) of individual photographs, and 2) an expert evaluation of the overall time series for each tagged whales individually by a team of five veterinary-pathologists familiar with large whales (Drs. Gulland, Moore, Norman, Raverty, and Rotstein). These show that the most common tag site conditions are swelling and depression. There were differences in the instances of these by species.

Tag site photographs scored for 34 gray and 63 blue whale tagging events (995 total images) revealed the median duration (±SD, range) of post-deployment follow-up in years was: 1.1 (±1.6, 0.055-4.189 - gray) and 5.4 (±4.8, 0.003-16.951 - blue). Swellings and depressions were the most common conditions observed at some point during tag follow-up. Swellings were noted in 25/34 (73.5%) of gray and 21/63 (33.3%) of blue whale events and depressions in 28/34 (82.4%) of gray and 45/63 (71.4%) of blue whales, respectively (Fig. 3). Proportional odds models used to assess severity scoring of swellings, depressions, and coloration changes at the tag site, collapsed over individual tagging events, revealed that species, years post-deployment, ventral placement of tag, and number of post-deployment encounters were significant predictors when included with lateral placement, sex, and tag type. For examining coloration changes, the same covariates were included in the model as maximum swelling and depression, with the addition of tag type. Based on likelihood ratio tests and AICs these models were found to be the most parsimonious The model for swelling severity revealed that, compared to gray whales, blue whales had significantly less severe swelling, while higher tag placement on the whale resulted in significantly less swelling severity. The increasing number of post encounters was significantly associated with increased severity of swelling, but likely reflects more opportunities to document swellings and their progression. Furthermore, whales with follow-up time of < 0.3 years had less severity swelling associated with a tag site. For depression severity, increasing post-deployment encounters were associated with more severe depressions, again likely reflecting a greater chance to observe a lesion over time. Depression severity significantly decreased with increasing years post-deploy follow-up which was often observed as the depression contracted in size over time and persisted over the duration of observed post-deployment. Severity of coloration was greater in gray whales compared to blue, as well in low/medium ventral tag placement compared to higher placement.

While most of the swellings were small, two blue whales (CRC ID 1573 and 2208) showed dramatically larger areas of swelling and were confirmed this year to both be the result of deployment of early satellite tags. Both had been tagged in 1995 by OSU with early versions of their tag which was external but was anchored with two long barbs (Mate et al. 2007). We suspect that these more extreme prolonged swellings were the result of one of these barbs breaking off and staying in the animal for an extended period. One of these two whales was extensively encountered by CICIMAR in the Gulf of California, Mexico and serves as a case study describing the long term sighting history of this individual described above (Gendron et al. 2014). This swelling as a result of tagging appeared to impeded the health and reproduction of

this whale which was regularly resighted in the Gulf of California; 2 of 3 years it had a calf prior to the swelling developing but had no calves in any of the 8 years during the swelling (Gendron et al. 2014).

RELATED PROJECTS

None of the animals tagged and the subject of this study were actually tagged as part of this research project and are from previous or current project funded separately, many of them with support from ONR. Analysis of the follow up satellite tagged PCFG gray whales conducted under this project has also been undertaken by OSU more focused on some of the more short term portions of the follow up and Cascadia more focused on longer term follow up.

ACKNOWLEDGMENTS

Bruce Mate and Craig Hayslip at OSU assisted in identifying the satellite tagged whales. Scott Baker and Debbie Steele conducted genetic identifications. Stephanie Norman conducted helped generate the tag site scoring system and conducting evaluation of photographs. Our Veterinary pathology team included Stephanie Norman, Stephen Raverty, Francis Gulland, Michael Moore, and David Rotstein. Annie Douglas worked with OSU on initial identification of the tagged blue whales. Alie Perez conducted the identifications of the tagged gray whales. Kiirsten Flynn conducted the photo selection, scoring, and data compilation. Collaborators including CICMAR (Diane Gendron), MICS (Richard Sears and Christian Ramp), Michael Fishback, Jeff Jacobsen, Dawn Goley, and others assisted in providing important photographs and data for assessment of tagged animals.

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